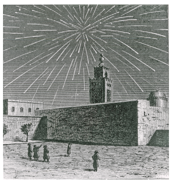
Meteors, Meteor Showers and the Draconids



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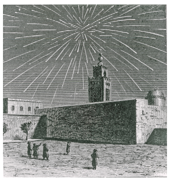
Meteors: Pieces of 'Heaven' Coming Down to Earth

1. By 1800, the celestial nature of comets was well established.
2. But with a few exceptions (e.g. Halley 1714; Pringle 1759; Rittenhouse 1783), ideas about meteors and meteorites remained firmly rooted in Aristotelian dogma.
   - i.e., meteors are atmospheric phenomena (which they are); perhaps similar to lightning or the aurora borealis (which they are not!).
3. Ancient Babylonian and early Greek ideas about meteoric phenomena well known; but dominant scientific view remained one of disbelief, e.g:
   - "Falling of stones from the sky is physically impossible" (Paris Academy of Sciences, 1772).
   - "How sad it is that the entire municipality enters folk tales upon an official record, presenting them as something actually seen . . ." (Claude Louis Berthollet; c.1790, after fall of the Barbotan meteorite, France, having been witnessed by local mayor and city council!).
4. However, Ernst Chladni (c.1794) concludes meteorites must be extraterrestrial; and that it is their flight through atmosphere that causes the phenomenon known as a meteor or fireball.

Establishing a Link: Meteors from Comets

1. Exploding fireball; fall of stones, at L'Aigle, Northern France, 1803 April 26.
2. Event witnessed by thousands; investigated by Jean-Baptiste Biot, who confirms event and its extraterrestrial source.
3. Leads to new science of meteoritics, and to new paradigm: i.e. cosmic origin of meteorites finally agreed.
4. But origin of meteors remains unresolved until after the great display of Leonid meteors on 1833 November 13.

Medieval fall of stones, 1557.



Meteor storm, after R.S. Ball (1893).

Leonids and Great Meteor Shower of 1833

1. Observations go back to 899 AD; a reliable annual display observed mid-November. Meteors come from 'head' of constellation Leo.
2. However, roughly every 33 years, the Leonids produce exceptionally intense displays, e.g. rare outbursts and meteor storms.
3. Olmsted and Twining (1834): first to draw causal connection between comets and meteors; after famous 1833 storm.
4. But yet another generation passes before cometary link finally established. In case of Leonids, Comet 55P/Tempel-Tuttle discovered 1865; period ∼33 yr.

Meteoroid Stream Formation in Solar System: Old View

1. Dust released from comet; particles spread out ahead of and behind comet in its orbit.
2. Dust disperses all around orbit. Produces a broad 'meteor' stream; highest dust density near parent comet.
   - ⟹ more intense meteor showers correlate with orbital period of parent comet.
   - And smooth dust distribution within trail.
3. Dust diffuses into interplanetary complex to form zodiacal cloud.

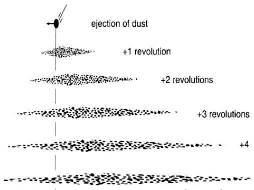
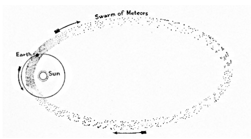


Image from Jenniskens (2006).



Broad meteor stream around cometary orbit.

Old View of Meteor(oid) Streams — II

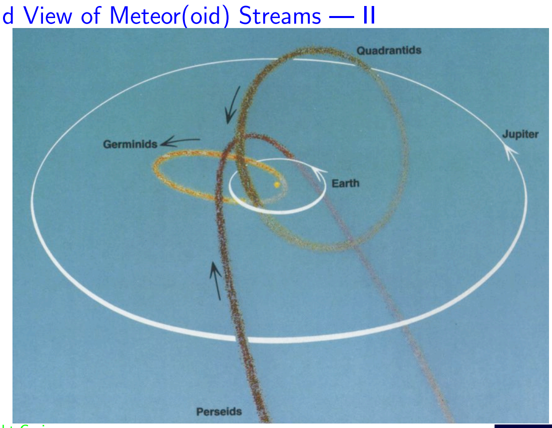
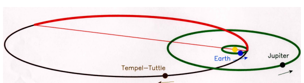


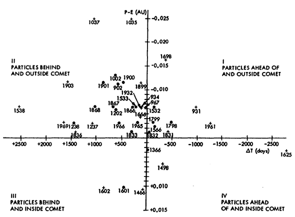
Image credit: Geert Barentsen

Case of Leonids: Dust Density Around Comet

1. With few exceptions, work focuses on determining the dust distribution around the comet in its orbit.
2. ⟹ Predictions of meteor storms; but very limited success.
3. Sometimes a storm happens years after the comet's most recent perihelion passage; sometimes an apparently promising geometry produces a 'damp squib'.



Tempel-Tuttle orbit; courtesy David Asher.

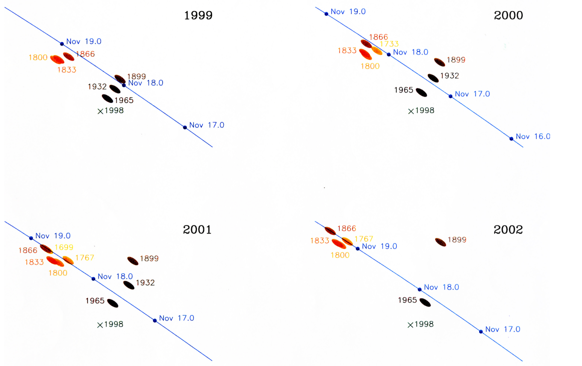


Modelled dust distribution around comet Tempel-Tuttle. Image credit Don Yeomans.

New Discoveries: The Leonid 'Season' of 1998 et seq.

1. Dust dynamics is relatively simple: grains move on elliptical orbits dominated by gravity and radiation pressure.
2. Dust trails produced by comet at each perihelion passage. Trails retain coherence for a dozen or more revolutions.
3. Successive orbits produce a complex of discrete trails. Trails are long and thin compared to background meteor stream.
   - Trail widths ≈10–20 Earth diameters ($D_\oplus$); trail lengths $\approx 10^5\, D_\oplus$.
   - Trails disperse into background stream (width $\approx$1,000 $D_\oplus$) through discrete planetary perturbations.
4. Discoveries pioneered by Kondrateva, Murav'eva & Reznikov and earlier workers. Independently developed by David Asher and Rob McNaught in 1990s; the first detailed predictions for Leonid meteors.
5. A step change in meteor science. Previous predictions subject to errors of hours, days and even years; new predictions for shower maxima agree with observations to better than 10 minutes!

New View of the Leonids: Earth in the Cosmic Firing Line



Images courtesy David Asher.

The Draconids – I: The Comet and its Orbit

21P/Giacobini-Zinner, 1998 November 1. Image credit: N.A. Sharp NOAO-AURA-NSF.

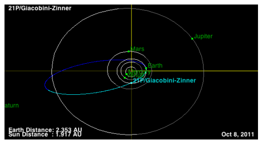


Image credit: NASA/JPL/Caltech.

21P/Giacobini–Zinner
2011 Oct 8

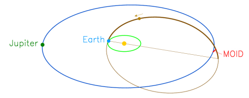
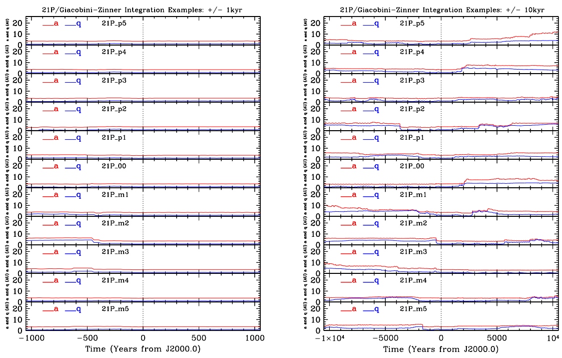


Image courtesy David Asher. Note potential for close approaches to both Earth and Jupiter.

21P/Giacobini-Zinner: Orbital Elements and Evolution

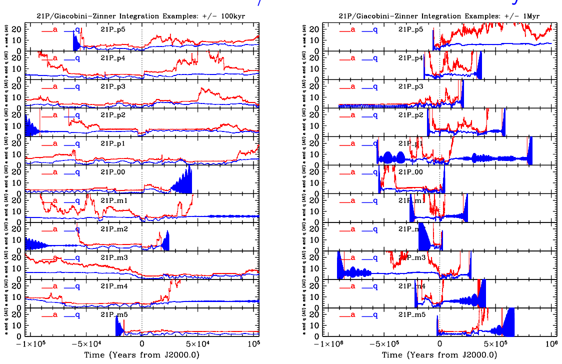
1. A typical Jupiter-family comet; discovered by Michel Giacobini on 1900 December 20; re-discovered by Ernst Zinner 1913 October 23.
2. Present orbit: semi-major axis $a = 3.53$ AU; perihelion distance $q = 1.04$ AU; inclination $i = 31.8$ degrees; orbital period $P = 6.62$ yr; next perihelion passage: 2012 February 11.
3. Long-term integrations suggest that current orbit is surprisingly stable; no really large changes within ± 2 kyr of present day. Suggests:
   - Parent comet probably physically highly evolved. Expect a largely inert crust, depleted in volatiles.
   - Outgassing probably from just a few active areas, perhaps variable in time.
   - A low-density meteor stream, but with fine structure and trails dependent on recent cometary activity.
4. Original 'source' orbit indeterminate: either from Oort cloud or near-Neptune trans-Neptunian zone (not Kuiper belt).

Evolution of Clones of 21P/Giacobini-Zinner: ± 10 kyr



11 clones of 21P/Giacobini-Zinner: $-1 < t < 1$ kyr and $-10 < t < 10$ kyr. (Image credit: Johnston, Asher, Bailey 2010)

Evolution of Clones of 21P/Giacobini-Zinner: ± 1 Myr



11 clones of 21P/Giacobini-Zinner: $-100 < t < 100$ kyr and $-1 < t < 1$ Myr. (Image credit: Johnston, Asher, Bailey 2010)

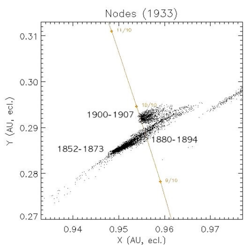
The Draconids – II: History and Previous Showers

1. Draconid meteors generally a very weak shower, observable for a few days around October 8/9 each year.
2. Occasional meteor storms or outbursts have been seen, e.g. 1933, 1946; and 1926, 1952, 1985, 1998.
3. The predicted 2011 outburst will be the last good display for more than 50 years.
4. Caveats for predictions:
   - Comet undergoes occasional 'outbursts' (sudden brightenings), e.g. early October 1946, and in August, September and October 1959. Any 19th-century outburst (obviously unknown) could affect present stream structure and hence predictions.
   - Comet orbit not known with high precision prior to 1900 owing to (1) close approaches to Jupiter, and (2) uncertain (and variable) non-gravitational forces due to outgassing from active regions.
   - Dust size distribution uncertain: Draconid meteoroids are slow ($V \simeq 21\,\mathrm{km\,s^{-1}}$), fragile, and often faint; so difficult in moonlight. Bright ones (up to Jupiter), and occasional fireballs, are also seen.

Previous Storms and Outbursts – 1933 October 9

Storm observed around 8.00 p.m. by W.F.A. Ellison (Armagh Observatory).

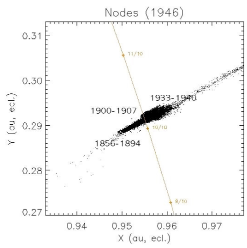
He writes: "Between 7 and 7.35 p.m. I counted 300 meteors. The majority were small objects of the 3rd and 4th magnitudes, but brighter ones were frequent, and occasionally there were brilliant flashing fireballs which lighted up the landscape like sheet lightning ... Called indoors for the evening meal at 7.35, I was out again at 7.58. Then it was apparent that a really great meteoric storm was in progress. I counted 200 meteors in two minutes, and then counting became impossible. The fire-stars became as thick as the flakes of a snowstorm ... they came in flocks and gusts. The sky was thick with them wherever one looked. ... I should call 400 per minute an under-estimate."



Passage of Earth through low-density 19th-century trails and then, nearly centrally, through dense trails released by the comet in 1900 and 1907. Image credit: Vaubaillon et al. (WGN, Journal of the IMO, 39, 59–63, 2011).

Previous Storms and Outbursts – 1946 October 10

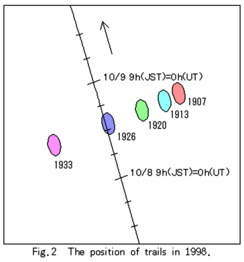
1. Storm observed around 03:50.
2. ZHR $\simeq$ 2000 to 5000 (some authors give values ranging up to 15,000).
3. Duration of main storm approximately one hour.
4. Noteworthy for one exceptional blue-white fireball: the train lasted more than 3 minutes.
   - cf. weak 1926 shower: another exceptional fireball (probably from the 1913 two-revolution trail); train lasted c.30 minutes.
5. First meteor shower to be detected by radar.



Passage of Earth through low-density 19th-century trails and nearly centrally through dense trails released by the comet in 1900 and 1907 and young 1933/1940 trails. Image credit: Vaubaillon et al. (WGN, Journal of the IMO, 39, 59–63, 2011).

Previous Storms and Outbursts – 1998 October 10

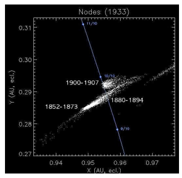
1. First Draconid outburst to be predicted with precision (Reznikov et al. 1993).
2. Observed around 13:10.
3. ZHR $\simeq$ 300 to 800.
4. Duration approximately one hour.
5. Dominated by faint meteors, fainter than star Polaris.
6. Comparable in flux and brightness distribution with outburst of 1985.
7. Circumstances difficult: just three days after Full Moon.

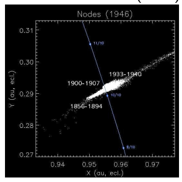


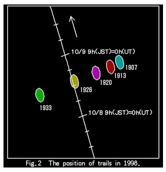
Passage of Earth in 1998 through edge of 1926 trail. Image credit: M. Sato..

Comparison Between Recent Draconid Events — Summary

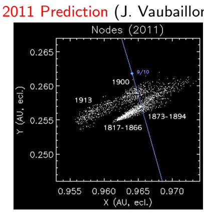
Two storms: 1933 and 1946. Image credits J. Vaubaillon (2011).







1998 Outburst (M. Sato).



2011 Prediction (J. Vaubaillon).

Predictions for 2011 Outburst

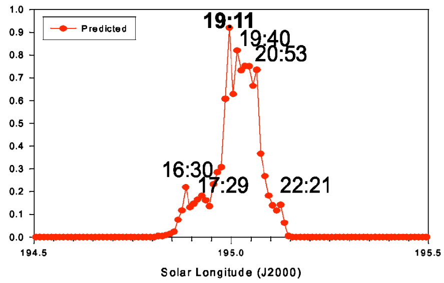


Image credit: Cooke & Moser (NASA, Marshall Space Flight Center)

NB: (1) Times in UT; (2) Early peaks (c.16:30, 17:30, 18:00) more uncertain — due to dust released in 1880, 1887, 1894, before comet discovered; (3) Main peaks due to dust released in 1900, 1913, therefore more secure.

Summary of 2011 Predictions

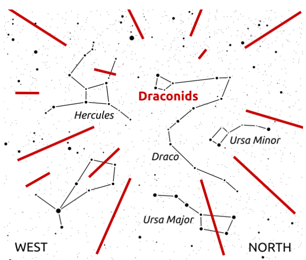
1. Expect meteor activity from c.16:00 to 21:00 (UT); passage of Earth through complex of dust trails released during 19th and early 20th centuries (1817–1866; 1873–1894; 1900 and 1913).
2. Estimates range from $\approx$10 meteors per hour between 16:30 and 17:30 UT, due to trails released in 1880, 1887 and 1894, to several tens per hour during same period, comprising relatively bright meteors.
3. Earth goes through 1900 trail between c.19:00 and 20:50 UT.
4. Expect $\approx$50–500 meteors per hour, peaking from c.19:45 to 20:15 UT.
   - A much higher flux, but much fainter meteors; observationally much more difficult.
5. Overall: Slow rise in activity from c.16:30 UT. Bright meteors at first, followed by increased flux of fainter meteors and rapid decline in activity after c.20:30 (UT).

What They (the Experts) Said: Some Quotable Quotes

1. "…current meteor forecast models predict a strong Draconid outburst, possibly a full-blown storm, on October 8, 2011" … [Which means we are going to see — what?] "… given the nearly full Moon and the fact that the Draconids are usually faint, the answer is not much." (Bill Cooke, 2010).
2. "…the author does not expect very strong Draconid activity in 2011. Trails 1887 and 1894 are not dense … the majority of meteors will be produced by 1900 trail … It is expected that the max ZHR will most probably be within 10–100." (Mikhail Maslov 2006).
3. "Draconids are often faint, difficult in moonlight." (Tony Markham 2011).
4. "… my own guess is that it will be visually less impressive than the Perseids in an average 'dark-of-Moon' year … That said, it's hugely important meteor science … a very unusual outburst." (David Asher 2011).

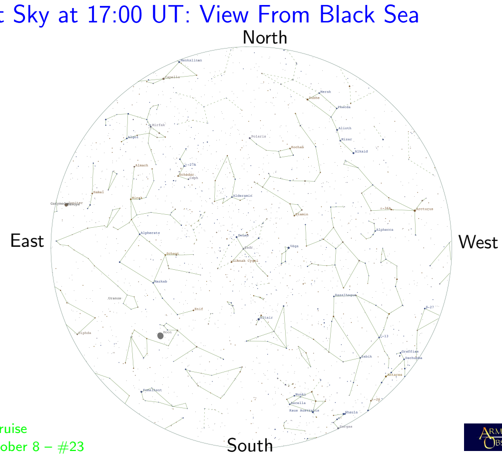
What to Look For and Where to Look

1. Get dark-adapted and avoid bright moonlight.
2. Look away from the Radiant, preferably to NW or SW; i.e. away from Moon.
3. Count meteors seen; note speed, direction and colours of any bright meteors, and any colours. Note duration of any persistent trains.
4. Draconids are relatively slow ($V \simeq 21\,\mathrm{km\,s^{-1}}$); the meteoroids are fragile and disintegrate at high altitude c.100 km.
5. Identify Radiant; is it a point or disc on the sky. Can you see any 'stationary' meteors?



Radiant of Draconid meteors, early evening 2011 October 8. Image credit: G. Barentsen (Armagh Observatory and International Meteor Organization); see http://www.imo.net/draconids2011.

Night Sky at 17:00 UT: View From Black Sea



Acknowledgements

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